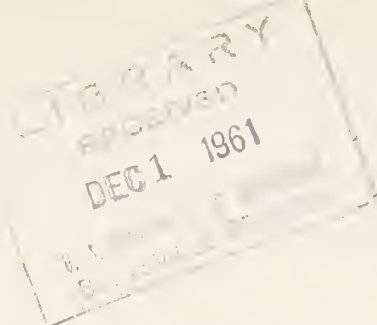


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A58.9
R31
#61



ARS 42-61
November 1961



Growth Through Agricultural Progress

UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Research Service

COMPARISON OF LOAD CHARACTERISTICS OF QUICK-RECOVERY
AND STORAGE-TYPE WATER HEATERS^{1/}

by

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Quick-recovery water heaters offer to consumers a number of advantages not possessed by the storage-type water heaters. (Strictly speaking, quick-recovery water heaters are also of the storage type; however, in this article storage-type water heaters are considered as those with heating elements of approximately 30 watts per gallon of tank capacity.) Advantages of quick-recovery water heaters include greater recovery rate, lower cost, and smaller space requirement. A disadvantage of this type is its unsuitability for use with off-peak controls, and therefore off-peak rates, because its water storage capacity is only 40 gallons. This quantity is too small for residences with modern laundry equipment unless energy is available continuously.

In recent years in rural areas water usually has been heated with L.P.-gas or storage-type electric water heaters. Quick-recovery water heaters were developed to provide electric water heaters with features previously found only in those using gas.

The quick-recovery water heater is capable of heating 18.4 gallons of water from 60° to 160° F. in 1 hour. The 30-gallon L.P.-gas water heater, the most popular size, can heat 25.2 gallons of water from 60° to 160° F. in a like period. Although the recovery rate of the quick-recovery water heater is less than that of the gas, the 10 gallons of extra storage capacity makes both types comparable in performance for normal house or farm use.

The price of a gas water heater may be less than that of a quick-recovery water heater as selling prices are related to water storage capacity. However,

^{1/} The material in this paper reports results of cooperative research between the Agricultural Engineering Department, Iowa Agricultural and Home Economics Experiment Station, and the Agricultural Engineering Research Division, ARS, USDA. Journal Paper No. J-3822 of the Iowa Agricultural and Home Economics Experiment Station, Ames, Iowa. Project No. 1282.

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if the costs of a pressure regulator, gas line, gas storage tank, and electrical branch circuit are properly assigned to the respective heaters, the installed costs of both types are about the same.

The energy costs of quick-recovery and L.P.-gas water heaters depend upon the prices of gas and electricity. If gas is purchased in bulk for house heating, it is generally less costly than electricity for water heating. If gas is purchased in small quantities, as normally would be the case for cooking and water heating, the operating cost of gas water heaters usually is as great as for those of the electric type.

The space requirements of quick-recovery and gas water heaters are similar. An electric water heater, however, has the advantage of not requiring a flue or chimney. This permits locating the heater near the point of maximum hot water use, or in some cases, installation in out-of-the-way spaces.

COMPARISON OF LOAD CHARACTERISTICS

Quick-recovery water heaters have not been promoted as aggressively by the managements of many power suppliers serving rural areas as their advantages warrant. One reason for this position may be the lack of information as to the load characteristics of this equipment. To supply additional information on this subject, five Iowa power suppliers^{3/} cooperated with the Farm Electrification Research Branch, Agricultural Engineering Research Division, ARS, USDA, and the Iowa Agricultural and Home Economics Experiment Station in a study to compare the load characteristics of quick-recovery and storage-type water heaters.

Selection of Consumers

Each cooperating power supplier selected four farms for study: Two farms used quick-recovery and the other two, storage-type water heaters. Each farm had approximately the same number of people and electric energy use. The farms with quick-recovery water heaters, however, had greater numbers of automatic washing machines, clothes driers, and ranges. Table 1 shows some information about the farms selected that may influence load characteristics.

^{3/} Allamakee-Clayton Electric Cooperative, Postville; Benton County Electric Cooperative, Vinton; Harrison County Rural Electric, Woodbine; Iowa Electric Light and Power Company, Muscatine; and Nishnabotna Valley Rural Electric, Harlan.

TABLE 1.--Information on farms in water heater study--Iowa 1959

Farm No.	Number of people		Major appliances			
	Adults	Children	Automatic washer	Clothes drier	Range	Other ^{1/}
QUICK-RECOVERY WATER HEATER						
1	2	3	X	X	X	-
2	2	1	X	X	X	A
3	2	4	-	X	-	-
4	2	4	-	X	X	-
5	3	5	X	-	X	-
6	2	3	X	X	X	-
7	2	3	-	X	X	-
8	2	3	-	-	X	-
9	4	0	X	X	X	B
10	2	1	X	X	X	-
Totals	23	27	6	8	9	-
STORAGE-TYPE WATER HEATER						
11	2	4	X	-		
12	2	2	-	-	X	A
13	2	4	-	X	-	-
14	2	4	-	X	X	-
15	3	3	-	-	X	-
16	2	3	-	-	X	-
17	2	3	-	X	X	-
18	2	2	-	-	-	-
19	3	0	X	X	X	C
20	2	1	-	-		-
Totals	22	26	2	4	6	-

^{1/} A = House electrically heated.

B = Second quick-recovery water heater in milkhouse and 3 space heaters of 4,800 watts used for supplementary heating.

C = 5 hp. elevator and 5 hp. grinder.

The electric demands of the 20 water heaters and 19 of the 20 farms were metered with 15-minute-interval recording demand meters. Considerable rewiring would have been required to install a demand meter on the main service of Farm No. 18. The meters were operated for approximately 1 month beginning with September 22, 1959. A photograph of one of the quick-recovery water heaters and the meters used with it is shown in Figure 1.

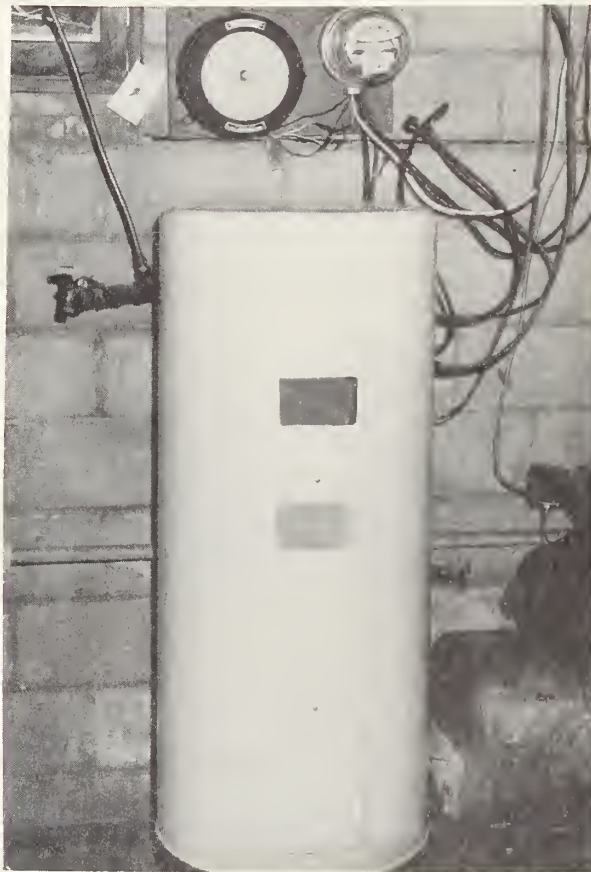


Figure 1.--One of the quick-recovery water heaters and the metering equipment used in study.

Effect on Individual Farm Demands

Some of the information obtained on the electric load characteristics of the individual farms and water heaters is shown in Table 2. The heating elements and thermostats of water heaters on Farms 5, 6, and 18 were connected so that both the top and bottom elements could be in operation at the same time. Since this connection is not recommended by most power suppliers, information on these farms was omitted from the averages.

With Farms 5, 6, and 18 omitted, the average energy consumptions of the two groups of farms and water heaters were about the same. Maximum demands of quick-recovery water heaters and farms with this type of water heater were greater than those with the storage type. The metered demands exceeded the rated demands of seven of the water heaters. These demands occurred at night when other loads were light and voltages at the water heater terminals were above the rated 230 volts.

Coincidence factors, defined here as the percent of the water heater maximum demand occurring during the farm maximum demand, of farms with quick-recovery water heaters averaged less than those with storage-type water heaters (Table 2). Both groups, however, had high coincidence factors showing that the water heaters were generally in operation for most of the peak demand periods.

As defined, the product of the coincidence factor and the water heater maximum demand gives the contribution of the water heater to the farm maximum demand. Quick-recovery water heaters added an average of 3,456 watts, and the storage-type water heaters an average of 1,561 watts, to the peak demands of the associated farms. This means that quick-recovery water heaters added an average of 1,895 watts more to the demands on the individual transformers and farm services than those of the storage type.

The demands of farms with quick-recovery water heaters averaged 2,200 watts more than those with the storage-type water heater as shown in Table 2. This higher load is attributable to the greater number of major appliances on these farms as well as to the presence of quick-recovery water heaters.

In some instances the higher demands of quick-recovery water heaters may cause voltage-drop problems. However, larger transformers and services or moving the transformer closer to the load center should correct such problems.

TABLE 2.--Electric load characteristics of farms and water heaters--October 1959

Farm No.	Heater rating		Heater size Gal.	Average daily energy use		Max. 15-min. demand		Coincidence factor %	Load factor	
	Top Watts	Bottom Watts		Water heater Kw.-hr.	Farm Kw.-hr.	Water heater Kw.	Farm Kw.		Water heater %	Farm %
QUICK-RECOVERY WATER HEATERS										
1	4500	4500	40	17.4	35.5	4.9	10.0	90.1	14.8	14.8
2	4500	4500	40	11.8	65.7	4.4	11.8	89.4	11.2	23.2
3	4500	4500	40	5.5	19.8	4.1	7.2	81.9	5.6	11.5
4	4500	4500	40	7.6	22.8	4.7	10.4	71.9	6.7	9.1
5 ^{1/}	4500	4500	40	21.4	43.8	8.4	12.0	84.8	10.6	15.2
6 ^A	4500	4500	40	14.7	36.2	7.3	11.4	81.3	8.4	13.2
7	4500	4500	40	7.9	21.6	4.7	10.4	69.4	7.0	8.7
8	4500	4500	40	9.5	18.6	4.3	6.8	64.5	9.2	11.4
9	4500	4500	40	8.2	36.4	4.5	11.6	70.4	7.6	13.1
10	4500	4500	40	15.5	--	4.4	--	--	14.7	--
Av. ^{2/}	4500	4500	40	10.4	31.5	4.5	9.7	76.8	9.6	13.1
STORAGE-TYPE WATER HEATERS										
11	1500	1000	52	9.4	23.8	1.4	3.2	88.5	28.0	31.0
12	2000	1250	66	13.3	74.9	2.0	14.4	98.0	27.7	21.6
13	2000	1250	66	19.3	29.4	2.0	3.0	88.5	40.2	40.7
14	1500	1000	52	6.8	28.1	1.6	9.2	91.8	17.7	12.7
15	1500	1000	52	14.9	42.6	1.7	6.0	74.7	36.5	29.6
16	1500	1500	52	6.0	29.4	1.7	6.0	76.3	14.7	20.4
17	1500	1000	52	7.0	18.9	1.1	7.8	94.3	26.5	10.1
18 ^A	1250	750	40	6.0	16.4	1.6	2.2	66.7	15.6	31.0
19	2500	2500	82	16.1	49.6	3.0	11.8	91.8	22.3	17.6
20	2000	2000	66	5.0	23.1	2.0	6.0	76.3	10.4	16.0
Av. ^B	1778	1389	60	10.9	35.5	1.8	7.5	86.7	24.9	22.2

1/ A = Thermostat wired so that both heating elements could be on at the same time.

2/ B = Data from Farms 5, 6, and 18 omitted from averages.

The load factors--the average demand divided by the maximum demand--of the quick-recovery water heaters averaged 9.6 percent as compared with 24.9 percent for those of the storage type. Load factors of farms with quick-recovery water heaters averaged 13.1 percent as compared to 22.2 percent for those with storage-type water heaters. Smaller heating units operating for longer periods of time are a reason for the greater average load factor for the farms in the latter group. Contributing to the smaller load factors of farms having quick-recovery water heaters may be the larger number of ranges and clothes driers found within this group.

Even though the load factors of storage-type water heaters were greater on the average than those of the quick-recovery type, load factors of quick-recovery water heaters are considerably greater than those of most house appliances. For example, earlier studies showed that ranges and clothes driers have average load factors of less than 3 percent. Thus quick-recovery water heaters are desirable loads for power suppliers insofar as their effects on the demands of individual farms are concerned although not so desirable as those of the storage type.

Effect on Group Load Characteristics

Managements of distribution systems are concerned about the contributions of particular appliances to system peak demands. To show the contributions of the two types of water heaters to system demand, average daily load curves of the water heaters and farms were prepared from the information collected in the study. Data were omitted for the two farms having quick-recovery water heaters with heating elements connected so that both could operate at the same time.

Daily load curves are shown in Figure 2. Each 15-minute period on the load curve represents the average demand computed by averaging daily demand readings of corresponding periods for 7 days for the farms in the respective group. A plot of the values thus obtained showed that the curves representing the demands of the two types of water heaters were irregular and crossed frequently. To obtain daily load curves more nearly representative of large groups of water heaters or farms, the data were smoothed by averaging into each value the demands for the 15-minute periods immediately preceding and following, giving a moving average obtained from 3 consecutive periods.

The diversified demands of quick-recovery water heaters and farms with this type of heater were greater than those with the storage type between 8:30 a.m. and 12:30 p.m. and less during the mid-afternoon and night hours. The storage-type water heaters contributed 41 percent of the diversified peak demand of the group as compared to 36 percent for those of the quick-recovery type. On the whole, however, the contributions of the two groups to system demands were quite similar.

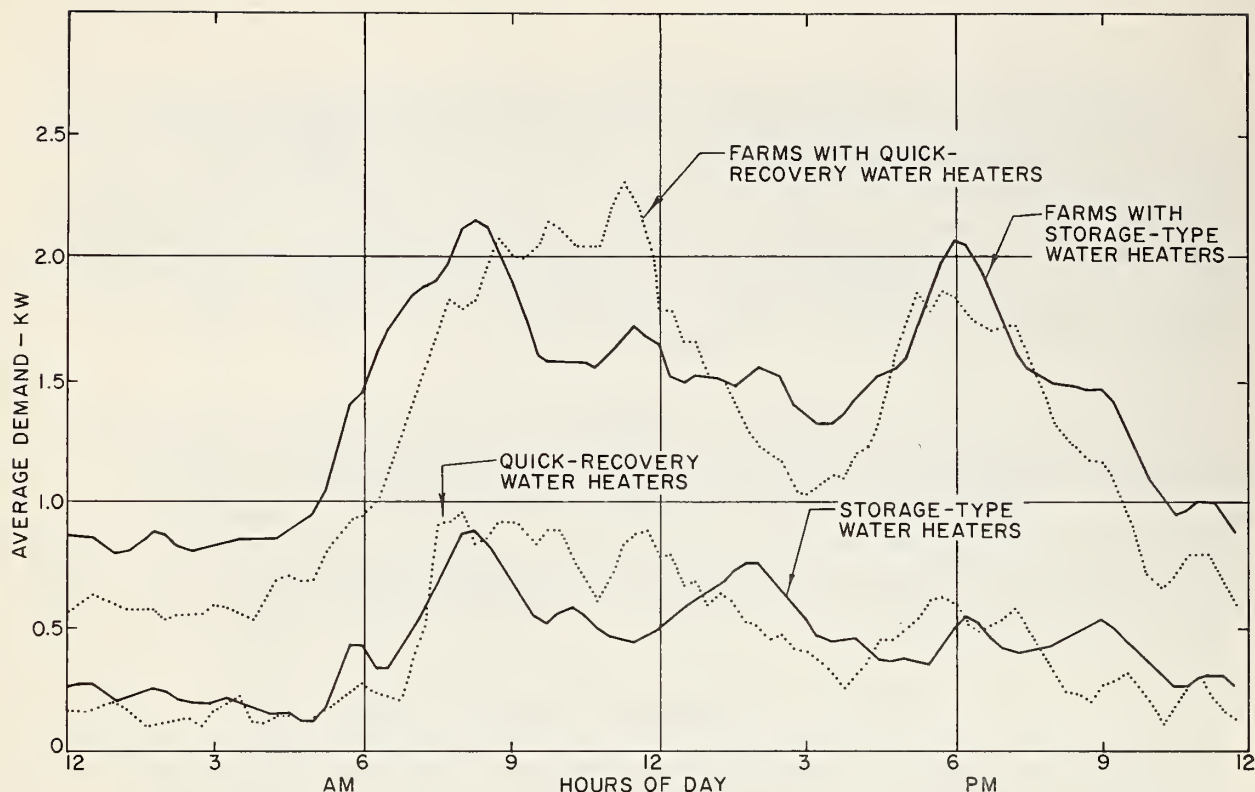


Figure 2.--Diversified average demands of farms and water heaters, October 4-10, 1959. Iowa.

The group load factors were 45 and 48 percent, respectively, for the quick-recovery and storage-type water heaters. Peak demands of both groups occurred in the morning rather than in the evening, the more usual time of the system peak. Earlier studies showed that the diversified load factors of groups of ranges and clothes driers are less than 15 percent. It is concluded that both types of water heaters have similar and very desirable group load characteristics.

SUMMARY

Quick-recovery water heaters add about 2,000 watts more to the 15-minute demands of individual consumers than storage-type water heaters. Because of this, in some instances, voltage problems may be caused by this load.

When groups of water heaters are considered, both types place about the same demand on the distribution system.

Although the load characteristics of storage-type water heaters are better in some respects than those of quick-recovery water heaters, both types are very desirable loads for power suppliers in that the load characteristics are better than those of most appliances.